

Detailed study 3: Energy from the nucleus

Chapter 8

Nuclear energy

- The nucleons are held together in the nucleus by a force of attraction called strong nuclear force, which is strong enough to overcome the electrostatic force of repulsion.
- (a) Fusion is the joining together of two nuclei to form a larger, more stable nucleus. Fission is the splitting of a single nucleus to form two smaller, more stable nuclei.
(b) Fusion
- In both cases, more stable nuclei than the original are being created. Excess energy is then released.
- From the graph (see figure 8.4, p. 200), binding energy per nucleon for ^{235}U is ≈ 7.8 MeV.
 \Rightarrow binding energy of $^{235}\text{U} = 235 \times 7.7$ MeV
 $= 1810$
 Binding energy after decay
 $=$ binding energy of ^{141}Ba + binding energy of ^{92}Kr
 $= 141 \times 8.4 + 92 \times 8.7$
 $= 1184.4 + 800.4$
 $= 1984.8$
 \Rightarrow Energy released $= 1985 - 1810$
 $= 175$
 ≈ 200 MeV
 (1 significant figure is appropriate considering data are required from graph.)
 Therefore, it is close to the accepted value.
- A flat mass has a much lower volume/surface area than a sphere. That is, for the same volume and mass as a sphere, more of the flat sheet is exposed to the air. This allows many more free neutrons to escape rather than sustain a chain reaction.
- Energy is released when fusing two small nuclei together because a larger, more stable nucleus results with a greater binding energy per nucleon.
- Similarities:*
 Each energy source is used to heat water, produce steam and turn turbines.
 The kinetic energy of the moving turbine in each plant is converted into electrical energy (via a generator).
 Electrical energy is distributed by other plants to the community via transformers and transmission lines.
Differences:
 Nuclear power is the initial energy source.
 A nuclear power plant does not produce CO_2 .
 Nuclear waste can be stored until harm to the environment is reduced.
- Control rods absorb neutrons that may split other uranium atoms. By absorbing these neutrons, the chain reaction can be slowed.
- The fuel for conventional reactors is uranium-235. The plutonium-239 used in fast breeder reactors is derived from uranium-238, which is more plentiful than uranium-235. Also, because plutonium-239 absorbs fast-moving neutrons, there is no need for a moderator to slow them down.
- The fuel in 'fast breeder' reactors (plutonium-239) readily absorbs fast-moving neutrons, whereas uranium-235 reactors using uranium-235 as fuel require a moderator to slow the neutrons down. Slow-moving neutrons are more likely to be captured by uranium-235.
- The list might include, for example:
Benefits: Good supply of fuel (in some locations), reduced production of greenhouse gases
Risks: Possible accidents causing large-scale environmental and human devastation, radioactivity of waste products
- Fissionable material is contained as two or more subcritical masses within a bomb. This allows safe transportation. These subcritical masses are brought together through the detonation of a small conventional bomb to reach critical mass (needed for a chain reaction to be sustained).
- Suggestions of location should be areas which are:
 - geologically stable
 - away from high density populations.
 Safety precautions should include:
 - secure location
 - inability for waste to leak
 - e.g. use of Synrock
 - dry area
 - space between waste and perimeter fence
 - discussion of shielding and half-life.
- Answers should be based on information contained on pp. 208 and 209 of text.
- Atmospheric testing:*
 The effects may remain for months/years as the radioactive fallout (with long half-lives) returns to the earth.
Underground testing:
 As the ground is a good shield, the effects are not as significant. There is little fall-out above ground level.
- Personal reflections of students